THE UNIVERSITY OF IOWA

IOWA CITY, IOWA 52240

*Department of Physics and Astronomy*
Area 319: 353-4343

# Research in Space Physics at the University of Iowa

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ANNUAL REPORT 1971



Prepared by

J. A. Van Allen, Professor of Physics and Head,
Department of Physics and Astronomy

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## 1. General Nature of the Work

As described more fully in previous reports, our broad objective is the extension of knowledge of the energetic particles in outer space and of their relationships to electric, magnetic, and electromagnetic fields associated with the earth, the sun, the moon, the planets, and the interplanetary medium.

Primary emphasis is (a) on observational work using a wide diversity of detectors on earth and lunar satellites and on planetary and interplanetary spacecraft and (b) on phenomenological analysis and interpretation.

Secondary emphasis is on closely related observational work by ground based radio-astronomical and optical techniques and on basic theoretical problems in plasma physics.

Specific fields of current investigation are the following:

(a) All aspects of the energetic particles that are trapped in the earth's magnetic field and are transiently present in the outer magnetosphere including the magnetospheric tail of the earth; and of the solar, interplanetary, and terrestrial phenomena that are associated with these radiations (e.g., solar flares, interplanetary magnetic fields and plasmas, aurorae, geomagnetic storms, corpuscular heating of the atmosphere, electromagnetic waves and electrostatic fields in the magnetosphere,

and the ionospheric effects of particle precipitation). This field of research was originated to a major extent by this laboratory.

(b) Galactic cosmic rays and energetic electrons, protons, alpha particles, and heavier nuclei emitted by the sun; and the interplanetary propagation of these particles, including the effects of shock waves.

(c) Radio-frequency emissions and soft X-radiation from both the quiescent and flaring sun and the implications thereof on the nature of the chromosphere and on the acceleration and emission of energetic particles in solar flares.

(d) Origin and propagation of very low frequency radio waves in the earth's magnetosphere and ionosphere.

(e) Shock waves in the interplanetary medium.

(f) The theory of wave phenomena in turbulent plasmas and of the origin of super-thermal particles.

(g) Dekametric radio emissions from Jupiter and the relationships of same to its magnetosphere.

(h) The magnetosphere and magnetic field of Jupiter and the search for magnetospheres of Saturn, Uranus, Neptune, and Pluto.

## 2. Current Projects

### (a) Injun V (Explorer 40)

Study and analysis of nearly 22 months of data from our low-altitude polar satellite Injun V (operating period 8 August 1968--30 May 1970) have been major activities of a large fraction of our research staff and students during the past year. This work is continuing. Injun V has already provided (i) the most complete observational and theoretical understanding of the polar aurorae that now exists; (ii) the first comprehensive survey of d.c. electric fields in the magnetosphere; (iii) the discovery of C,N,O nuclei trapped in the radiation belts of the earth; (iv) a massive body of observations on VLF radio waves in the magnetosphere and ionosphere; (v) new data on the spectra of low energy electrons and protons in the magnetosphere; and (vi) several studies of the access of solar energetic particles into the magnetosphere.

During the summer of 1970 Professor Pfotzer of the Max Planck Institut für Stratosphaerenphysik, Lindau/Harz, Germany expressed an interest in supporting Injun V flight operations and data acquisition for a special joint operation. In September, we "found" Injun V again (after a three months' lapse) and established that the spacecraft and most of the experiments were in good operating condition. After an extended period of negotiations and arrangements and with the permission and help of ONR and NASA

we resumed operations and data acquisition on 19 February 1971 and continued until 7 June 1971, at which time Injun V was "put-to-rest" for the second time for financial and administrative reasons. The satellite had been in flight for 34 months at that date, and was continuing in useful operating condition, the principal shortcoming being a deficiency in available power caused by partial failure of a "power dump circuit" relatively early in flight. Master science tapes from the joint American-German operation will be completed in late September. The data will be the subject of collaborative work.

(Hardware and other pre-flight support by Langley Research Center/NASA. Operation of the North Liberty Radio Observatory for telemetry reception and macro-data-reduction by the Goddard Space Flight Center/NASA. Experimenters' data analysis by Langley Research Center/NASA. Basic station facilities including 60 ft. dish, 28 ft. dish, receivers, recorders, microwave link and command antennas and transmitters at NLRO by Office of Naval Research)

[Van Allen, Frank, Gurnett, Shawhan, Fennell, Craven, Ackerson, Akersten, Anderson, Cauffman, Randall, Enemark, Brechwald, Rogers, Taylor, and supporting personnel at the University of Iowa; Krimigis and Verizariu at Applied Physics Laboratory of Johns Hopkins University; Sagalyn and Wildman at Air Force Cambridge Research Laboratory]

(b) Explorers 33 and 35

These two satellites carry similar pieces of University of Iowa equipment for study of the magnetosphere, solar energetic particles, solar X-rays, and particle effects of the moon.

Explorer 33 was launched into a very eccentric orbit on 1 July 1966 and has operated nearly continuously until transmitter drop-out on 31 May 1971 (59 months). An attempt will be made to revive it in late August 1971. The major part of the U. of I. detector array has functioned perfectly throughout.

Explorer 35 was launched on 19 July 1967 and inserted into lunar orbit three days later. Since that time the spacecraft and the U. of I. equipment have operated essentially perfectly and continuously, with the exception of significant degradation of the spacecraft power supply during the past six months.

These two spacecraft have provided a large volume of excellent data which has engaged the interest of a large number of research students and members of the staff.

During a lapse in NASA operational support for Explorer 33, 13 July 1970 to 28 March 1971, we acquired telemetry with our 60 ft. and 28 ft. dishes at NLRO. Data acquired during the period totaled 79,866 minutes or 1,331 hours. These data were also demodulated and digitized at our own facility with the help of a surplus set of comb filters from GSFC.

The same facilities were used recently to acquire data from Explorer 35 in support of the Apollo 15 operation.

(Data reduction and analysis since 1968 and NLRO telemetry reception supported by Office of Naval Research)

[Van Allen, Innanen, Catalano, Sentman, Burns, Spangler, Oliven, Yeh, Venkatarangan, Sarris at University of Iowa; Venkatesan at University of Calgary; Armstrong at University of Kansas; Krimigis at Applied Physics Laboratory/Johns Hopkins University]

(c) Explorer 43 (IMP-I) (1971-019A)

This NASA/GSFC spacecraft was successfully launched on 13 March 1971 into an eccentric earth orbit with the following initial parameters: period 94.3 hrs, inclination 28°.8, apogee 33.1 $R_E$, perigee 1.055 $R_E$. Two sets of University of Iowa experiments are on board. One consists of two dual-electrostatic analyzers for the comprehensive spectral measurement of electrons and protons (50 to 50,000 eV) in the magnetosphere and in interplanetary space. The other is a combination of radio receivers with electric and magnetic antennas for the study of VLF radio phenomena (10 Hz - 15 kHz) in the magnetosphere and in the solar wind. Both sets of experiments are operating perfectly. The NLRO facilities are being used for the reception of analog VLF data.

(Support jointly by GSFC/NASA and ONR)

[Gurnett, Pfeiffer et al. on VLF radio experiment]
[Frank, Yeager, Ketterer, Callahan, Owens on low energy particle experiment]

(d) Small Scientific Satellite ($S^3$-A)

The VLF radio group has collaborated with the University of Minnesota and the Goddard Space Flight Center in developing a set of flight apparatus for this mission, in a moderately eccentric orbit about the earth. Launch is now scheduled for November 1971.

(Support by GSFC/NASA)

[Gurnett, Shawhan, Anderson et al.]

(e) IMP-H and IMP-J

Work is progressing well on the construction of low energy proton-electron electrostatic analyzers (similar to those on IMP-I) for both of these two missions, as is work on a VLF radio experiment for IMP-J.

IMP-H is scheduled for launch ~ March 1972 and IMP-J, for ~ June 1973.

(Support by GSFC/NASA)

[Electrostatic analyzers, Frank et al.]
[VLF radio, Gurnett et al.]

(f) German-American Solar Probe (Helios)

VLF radio equipment is being built for this interplanetary spacecraft which is scheduled for ~ 1973 launch. The planned solar orbit will make it possible to measure interplanetary (solar-wind) and solar generated radio emissions (10 Hz to 15 kHz) from 1.0 to 0.3 A.U. from the sun.

(Support by GSFC/NASA)

[Gurnett, Pfeiffer et al.]

(g) British-American Near Earth Satellite (UK-4)

Low energy particle measurements similar to those on Injun V will be made in this mission, with emphasis on the auroral zone. Launch is scheduled for either November 1971 or January 1972.

(Support by GSFC/NASA)

[Frank, Craven, Enemark, Ketterer, Callahan]

(h) Pioneers F and G (Asteroid/Jupiter Missions)

These spacecraft are intended to fly outwards from the earth, through the asteroid belt and past the planet Jupiter at a closest distance of approach of $\lesssim 3$ planetary radii. After encounter, they will continue on trajectories such as to eventually escape from the solar system. The earth-Jupiter flight time is about 650 days. It may be possible to receive useful telemetry for as long as ten years.

The University of Iowa experiment is designed to make an exploratory survey of the intensities, energy spectra, and distribution of energetic electrons and protons in the radiation belts of Jupiter and to study the interplanetary propagation of solar electrons and protons to large heliocentric radial distances.

The flight unit for Pioneer F was completed and delivered in May 1971. The flight unit for Pioneer G is completely built and is now undergoing environmental tests and physical calibration. Beginning in October the prototype unit will be refurbished as the back-up unit for Pioneer G.

The launch window for Pioneer F is 28 February to 11 March 1972 and for Pioneer G, April 1973.

(Support by Ames Research Center/NASA)

[Van Allen, Randall, Enemark, Owens, Baker, Luthey]

(i) Injun VI (Injun F)

A twelve-month Design Study Contract (NAS1-10445) for Injun F was agreed upon by the Langley Research Center/NASA and the University of Iowa on 25 November 1970. This mission was proposed originally in December 1968 under the title "Proposed Investigation of the Earth's Polar Magnetosphere at Large Radial Distances". This (Phase B) design work has been proceeding during the past nine months toward a definitive, detailed design including an engineering test structure. The satellite is planned to weigh 58 pounds and to be launched by a five-stage Scout from the Pacific Missile Range into a 90° inclination orbit having apogee at 16 earth radii over the earth's north pole and perigee at an altitude of ~ 500 km over the south pole. Operational control of the satellite and most of the telemetry acquisition will be done by our North Liberty Radio Observatory.

The satellite will carry three basic scientific instruments for the investigation of the particles and the electric and magnetic fields associated with the earth's polar magnetosphere in the vicinity of the hypothetical magnetic neutral point.

(i) A four-range, three-axis Schonstedt flux-gate magnetometer to measure the vector magnetic field. (Presently planned full scale ranges on each axis are as follows: $\pm$ 100 gammas, $\pm$ 600 gammas, $\pm$ 3,000 gammas, and $\pm$ 10,000 gammas -- selectable by ground command.)

(ii) A Low-Energy Proton and Electron Differential Electrostatic Analyzer (LEPEDEA) to measure the differential energy spectra of protons and electrons, separately and simultaneously, over the energy range 4 eV to 40,000 eV for a wide range of intensities and the integral intensities of $\gtrsim$ 40 keV electrons and/or $>$ 600 keV protons.

(iii) An ELF-VLF Electric and Magnetic Fields apparatus to study the characteristics and origin of naturally occuring radio noises and plasma instabilities in the earth's polar magnetosphere and magnetosheath. The electric antenna (100 ft. tip-to-tip) and associated receiver depend on the successful experience with similar apparatus on Injun V and will operate over the frequency range 1 Hz to 30 kHz. The magnetic antenna (a search coil magnetometer) and its associated receiver cover the frequency range 1 Hz to 3 kHz.

A preliminary design review was conducted at LRC on 30 April 1971. The final design review under the present contract is scheduled for mid-October 1971. Tentative approval to proceed with construction of flight hardware is currently under consideration by NASA. If, after the final design review, full approval is given and a construction contract executed, we will plan on launch in late 1973.

(Design support by LRC/NASA)

[Van Allen, Frank, Gurnett, Rogers, Enemark, Craven, Oliven, Randall, Brechwald, Jagnow, Leimer of the University of Iowa and Cahill of University of Minnesota]

(j) Theory

Theoretical studies are being made on the propagation of solar protons, alpha particles, and electrons in interplanetary space; on the emission of X-rays and radio noise by the sun; on the generation and propagation of very low frequency radio waves in the magnetosphere and on the relationship of such waves to particle acceleration, diffusion, and precipitation; on waves in the interplanetary medium; and on the radiation belts of Jupiter.

(Support by ONR and NASA)

[Gurnett, Shawhan, Taylor, Luthey, Innanen]

(k) Solar Radio Noise

The Collins Radio Company 1.95 cm radiometer-polarimeter at the North Liberty Radio Observatory has recently been rebuilt and is being used for the study of radio flares on the sun. Special interest attaches to flares whose X-ray and particle emission is observed by Explorers 33 and 35 and Injun V.

(Support by ONR)

[Shawhan and Sarris]

(l) Electron Density in the Solar Corona

The occultation of the pulsar NP 0532 by the solar corona (closest approach of line of sight to center of the sun: 5 solar radii) has been observed in mid-June of three successive years 1969, 1970, and 1971 at the Arecibo Radio Observatory at three different radio frequencies (111.5, 196.5, and 430.0 MHz). The observations of dispersion measure as a function of time as the occultation proceeds yield absolute values of coronal electron density over the range 5 to 20 solar radii in an entirely new way and with much improved accuracy over existing values.

(Support by NASA)

[Rankin and Erskine]

(m) Spectro-Photometry of Planets

A program of absolute spectro-photometry of the planets Jupiter, Saturn, Uranus, Neptune, and Pluto and satellites of the major planets is underway, using the U. of Iowa 24" optical

telescope. The object is to increase knowledge of the nature of their surfaces and atmospheres. One paper on Pluto has been submitted for publication. The current work on Jupiter is of special interest to the space physics group.

(Support by NSF)

[Neff and Fix]

(n) Very-Long-Base-Line Radio Interferometry

A program of VLBI observations is being developed at NLRO in collaboration with Iowa State University/Ames, NOAA/Boulder, GSFC, and the National Radio Observatory in Greenbank, W. Va. In contrast to most other VLBI experiments, a low frequency, 26.5 MHz, has been selected in order to study the dekametric emissions from Jupiter and the structure of the interplanetary plasma. The first substantial series of observations is underway during August 1971.

(Support by NASA)

[Shawhan and Taylor]

3. Senior Academic Staff in Space Physics
[July 1971]

Van Allen, James A., Professor of Physics and Head of Department of Physics and Astronomy

Frank, Louis A., Associate Professor of Physics

Gurnett, Donald A., Associate Professor of Physics

Shawhan, S. D., Assistant Professor of Physics

Craven, John D., Research Associate

Oliven, Melvin H., Research Associate

Rankin, John M., Research Associate

Luthey, Joe L., Research Associate

Also in closely related work
(astronomy and plasma physics)

Montgomery, David C., Professor of Physics

Knorr, Georg, Associate Professor of Physics

Swift, Daniel F., Visiting Associate Professor of Physics
[September 1971]

Neff, John S., Associate Professor of Astronomy

Fix, John D., Assistant Professor of Astronomy

Joyce, Glenn R., Assistant Professor of Physics

4. Senior Engineering and Administrative Staff
[July 1971]

Enemark, Donald C., Research Assistant Professor of Physics

Brechwald, Robert L., Senior Computer Programmer and Systems Analyst

Rogers, John E., Project Manager

Robertson, Thomas D., Contracts Administrator

Anderson, Roger R., Research Physicist

Gabel, Ronald H., Research Physicist

Pfeiffer, G. William, Research Physicist

Yeager, David M., Research Physicist

Randall, Roger F., Research Physicist

Henry, Kaye, Drafting Shop Supervisor

Freund, Edmund A., Supervisor, Departmental Machine Shop

Robison, Evelyn D., Publications Supervisor

Swails, James K., Data Reduction Supervisor

Dunlavy, D. David, Station Manager, North Liberty Radio Observatory

5. Junior Academic Staff in Space Physics [July 1971]

All of those listed below are graduate students, engaged in research in space physics.

| | Appointment | Principal Research Project |
|---|---|---|
| Ackerson, Kent L. | Research Assistant | Auroral Particles (Injun V) |
| Anderson, Roger R. | Research Physicist | VLF Radio ($S^3$-A) |
| Baker, Dan W. | NSF Trainee and Research Assistant | Detector Calibrations (Pioneers F/G) |
| *Burns, Thomas B. | Research Assistant | Waves in Plasma (Theoretical) |
| Callahan, Timothy | Research Assistant | Detector Calibrations (IMP-I and UK-4) |
| Casey, David | Research Assistant | VLF Radio (Injun V) |
| *Catalano, Charles P. | U. S. Steel Fellow | Solar X Rays (Mariner V, Explorers 33/35) |
| Chen, Sha-Lin H. | Research Assistant | Solar Radio Emissions |
| **da Costa, José M. | NASA International Fellow | Detector Calibrations (Pioneers F/G) |
| Emery, Mark H. | Research Assistant | Plasma (Theoretical) |
| Erskine, Fred T. | Research Assistant | Pulsar Observations (Arecibo) |
| Flindt, Herbert R. | NDEA Fellow | Access of Solar Particles to the Magnetosphere (Theoretical) |
| Hosford, Norman | Research Assistant | VLF Radio |
| Innanen, William G. | Research Assistant | Interplanetary Propagation of Solar Particles (Explorers 33/35) |
| Ketterer, Harold E. | Research Assistant | Low Energy Magnetospheric Particles (IMP's H, I, and J) |

*Ph.D., August 1971
**M.S., August 1971

| | | |
|---|---|---|
| Randall, Bruce A. | NDEA Fellow and Link Foundation Fellow | Magnetospheric Protons, Electrons, and Alpha Particles (Injun V) |
| Rodriguez, Paul | Research Assistant | VLF Radio (Injun V) |
| Saflekos, Nicolaos | Research Assistant | Diffusion of Particles in the Magnetosphere (Theoretical) |
| **Sarris, Emmanuel | Research Assistant | Solar Radio Emissions |
| Sentman, Davis | Research Assistant | Solar Radio Emissions |
| Shaw, Robert R. | Research Assistant | VLF Radio (Injun V) |
| Sheu, Yung-Hung Tso | Research Assistant | Solar Radio Emissions |
| Shoucri, Magdi Mounir | Research Assistant | Plasma Physics (Theoretical) |
| Taylor, William W. L. | Research Assistant | Ionospheric Radio |
| Vahala, George M. | Research Assistant | Waves in Plasma (Theoretical) |
| Willhoit, Louis E. | Research Assistant | Analysis of Particle Data (Mariners IV/V) |
| Williams, James H. | Research Assistant | Plasma Physics (Theoretical) |
| Wing, William R. | Oak Ridge Fellow | Plasma Physics (Experimental) |
| Yeager, David M. | Research Physicist | Magnetospheric Particles (UK-4) |



** M.S., August 1971

## 6. Advanced Degrees Awarded in Space Physics at U. of Iowa 16 June 1970--31 July 1971

M.S. Degree

Sharad Gaur (August 1970), "Determination of Radio Source Characteristics Using the Very-Long-Baseline Interferometer"

Ph.D. Degree

Andrew A. Lacis (August 1970), "The Structure of White Dwarf Envelopes and Its Effect on the Thermal Cooling Rate"

David P. Cauffman (May 1971), "A Satellite Study of D.C. Electric Field Reversals in the Magnetosphere"

7. Research Reports and Publications in Space Science
16 July 1970--31 July 1971

P. R. SENGUPTA
Solar X-Ray Control of the E-Layer of the Ionosphere
J.A.T.P., 32, 1273-1282, 1970

J. A. VAN ALLEN
Catalog of Solar X-Rays
Solar-Geophysical Data [July 1970], SGD 311, Part II, 70
ESSA Environmental Data Service, U. S. Department of Commerce

J. A. VAN ALLEN
Catalog of Solar X-Rays
Solar-Geophysical Data [July 1970], SGD 311, Part II, 71
ESSA Environmental Data Service, U. S. Department of Commerce

SR. JEAN GIBSON, O.S.B., and JAMES A. VAN ALLEN
Correlation of X-Ray Radiation (2-12 A°) with Microwave Radiation (10.7 cm) from the Non-Flaring Sun
Astrophys. J., 161, 1135-1146, 1970

S. M. KRIMIGIS, P. VERZARIU, J. A. VAN ALLEN, T. P. ARMSTRONG, T. A. FRITZ, and B. A. RANDALL
Trapped Energetic Nuclei $Z \geq 3$ in the Earth's Outer Radiation Zone
J. Geophys. Res., 75, 4210-4215, 1970

M. A. SCHIELD and L. A. FRANK
Electron Observations Between the Inner Edge of the Plasma Sheet and the Plasmasphere
J. Geophys. Res., 75, 5401-5414, 1970

J. A. VAN ALLEN
Catalog of Solar X-Rays
Solar-Geophysical Data [August 1970], SGD 312, Part II, 86-87
ESSA Environmental Data Service, U. S. Department of Commerce

J. A. VAN ALLEN
Catalog of Solar X-Rays
Solar-Geophysical Data [August 1970], SGD 312, Part II, 88
ESSA Environmental Data Service, U. S. Department of Commerce

J. A. VAN ALLEN
Catalog of Solar X-Rays (January 1970)
Solar-Geophysical Data [September 1970], SGD 313, Part II, 106
ESSA Environmental Data Service, U. S. Department of Commerce

J. A. VAN ALLEN
Catalog of Solar X-Rays (February 1970)
Solar-Geophysical Data [September 1970], SGD 313, Part II, 107
ESSA Environmental Data Service, U. S. Department of Commerce

J. A. VAN ALLEN
Catalog of Solar X-Rays (March 1970)
Solar-Geophysical Data [September 1970], SGD 313, Part II, 70-71
ESSA Environmental Data Service, U. S. Department of Commerce

J. A. VAN ALLEN
Catalog of Solar X-Rays (April 1970)
Solar-Geophysical Data [October 1970], SGD 314, Part II, 60
ESSA Environmental Data Service, U. S. Department of Commerce

JAMES A. VAN ALLEN, BRUCE A. RANDALL, and STAMATIOS M. KRIMIGIS
Energetic Carbon, Nitrogen and Oxygen Nuclei in the Earth's Outer Radiation Zone
J. Geophys. Res., 75, 6085-6091, 1970

CARL HEILES, D. B. CAMPBELL, and J. M. RANKIN
Pulsar NP 0532: Properties and Systematic Polarization of Individual Strong Pulses at 430 MHz
Nature, 226, 529-531, 1970

J. M. RANKIN and CARL HEILES
Pulsar NP 0532: Polarization of Strong Pulses at 430 MHz as Seen with 300 kHz Bandwidth
Nature, 227, 1330-1331, 1970

J. M. RANKIN, J. M. COMELIA, H. D. CRAFT, JR., D. W. RICHARDS, D. B. CAMPBELL, and C. C. COUNSELMAN III
Radio Pulse Shapes, Flux Densities, and Dispersion of Pulsar NP 0532
Astrophys. J., 162, 707-725, 1970

JOSEPH F. FENNELL
Observations of Proton Bursts in the Magnetotail with Explorer 35
J. Geophys. Res., 75, 7048-7059, 1970

F. L. SCARF, R. W. FREDRICKS, L. A. FRANK, C. T. RUSSELL, P. J. COLEMAN, JR., and M. NEUGEBAUER
Direct Correlations of Large-Amplitude Waves with Suprathermal Protons in the Upstream Solar Wind
J. Geophys. Res., 75, 7316-7322, 1970

J. A. VAN ALLEN
Catalog of Solar X-Rays (May 1970)
Solar-Geophysical Data [November 1970], SGD 315, Part II, 71
ESSA Environmental Data Service, U. S. Department of Commerce

S. D. SHAWHAN, L. P. BLOCK, and C.-G. FALTHAMMAR
Conjugate Photoelectron Impact Ionization
J.A.T.P., 32, 1885-1900, 1970

S. D. SHAWHAN and D. A. GURNETT
Recent Rocket Measurements of AC Electric and Magnetic Fields in the Ionosphere
Plasma Waves in Space and Laboratory, Vol. 2, pp. 399-410
[Edinburgh University Press, Edinburgh-England:
J. O. Thomas and B. J. Landmark, Editors]

J. A. VAN ALLEN
Catalog of Solar X-Rays (June 1970; Addendum May 1970)
Solar-Geophysical Data [December 1970], SGD 316, Part II, 97-98
ESSA Environmental Data Service, U. S. Department of Commerce

P. VENKATARANGAN, D. VENKATESAN, and J. A. VAN ALLEN
Solar Flare Increases in Cosmic Ray Intensity on November 18, 1969; February 25, 1969; and March 30, 1969
Acta Physica Academiae Scientiarum Hungaricae, 29, Suppl. 2, 409-420, 1970
[Proc. 11th Int. Conf. on Cosmic Rays, Budapest 1969]

CARL HEILES, J. M. RANKIN, and D. B. CAMPBELL
Absence of Average Polarization at 111.5 MHz in Pulsar NP 0532
Nature, 228, 1074, 1970

S. M. KRIMIGIS
The Radial Gradient of 0.3 MeV Protons in Interplanetary Space, Measured with Mariner 5
Acta Physica Academiae Scientiarum Hungaricae, 29, Suppl. 2, 125-132, 1970
[Proc. 11th Int. Conf. on Cosmic Rays, Budapest 1969]

G. PIZZELLA and L. A. FRANK
Energy Spectrums for Protons (200 ev ≤ E ≤ 1 Mev) Intensities in the Outer Radiation Zone
J. Geophys. Res., 76, 88-91, 1971

J. A. VAN ALLEN
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Solar-Geophysical Data [January 1971], SGD 317, Part II, 88-89
ESSA Environmental Data Service, U. S. Department of Commerce

J. M. RANKIN, CARL HEILES, and J. M. COMELIA
Pulsar NP 0532: Disappearance of the Precursor Pulse Component at 606 MHz
Astrophys. J., 163, L95-L96, 1971

S. M. KRIMIGIS and P. VERZARIU
Implications on Particle Storage at the Sun from Observations of Solar-Flare Proton Spectrums
J. Geophys. Res., 76, 792-807, 1971

PAUL RODRIGUEZ and DONALD A. GURNETT
An Experimental Study of Very-Low-Frequency Mode Coupling and Polarization Reversal
J. Geophys. Res., 76, 960-971, 1971

STEPHEN R. MOSIER and DONALD A. GURNETT
Theory of the Injun 5 Very-Low-Frequency Poynting Flux Measurements
J. Geophys. Res., 76, 972-977, 1971

J. A. VAN ALLEN
Catalog of Solar X-Rays (August 1970)
Solar-Geophysical Data [February 1971], SGD 318, Part II, 66-67
ESSA Environmental Data Service, U. S. Department of Commerce

J. A. VAN ALLEN
Catalog of Solar X-Rays (September 1970)
Solar-Geophysical Data [March 1971], SGD 319, Part II, 60
ESSA Environmental Data Service, U. S. Department of Commerce

STEPHEN R. MOSIER
Poynting Flux Studies of Hiss with the Injun 5 Satellite
J. Geophys. Res., 76, 1713-1728, 1971

JAMES A. VAN ALLEN and BRUCE A. RANDALL
Evidence for Direct Durable Capture of 1- to 8-Mev Solar Alpha Particles onto Geomagnetically Trapped Orbits
J. Geophys. Res., 76, 1830-1836, 1971

ROBERT R. SHAW and DONALD A. GURNETT
Whistlers with Harmonic Bands Caused by Multiple Stroke Lightning [Letter to Editor]
J. Geophys. Res., 76, 1851-1854, 1971

JERRY F. DRAKE
Characteristics of Soft Solar X-Ray Bursts
Solar Physics, 16, 152-185, 1971

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Catalog of Solar X-Rays (October 1970)
Solar-Geophysical Data [April 1971], SGD 320, Part II, 64
ESSA Environmental Data Service, U. S. Department of Commerce

L. A. FRANK
Relationship of the Plasma Sheet, Ring Current, Trapping Boundary, and Plasmapause Near the Magnetic Equator and Local Midnight
J. Geophys. Res., 76, 2265-2275, 1971

G. PIZZELLA and B. A. RANDALL
Differential Energy Spectrum of Geomagnetically Trapped Protons with the Injun 5 Satellite
J. Geophys. Res., 76, 2306-2312, 1971

L. A. FRANK
Comments on a Proposed Magnetospheric Model
J. Geophys. Res., 76, 2512-2515, 1971

DONALD A. GURNETT, STEPHEN R. MOSIER, and ROGER R. ANDERSON
Color Spectrograms of Very-Low-Frequency Poynting Flux Data
J. Geophys. Res., 76, 3022-3033, 1971

C. C. COUNSELMAN III and J. M. RANKIN
Multipath Delay Distortion of Radio Pulses from NP 0532
Astrophys. J., 166, 513-523, 1971

CARL HEILES and JOHN M. RANKIN
Frequency Structure in Individual Strong Pulses of NP 0532
Nature (Physical Science), 231, 97-99, 1971

L. A. FRANK and K. L. ACKERSON
Observations of Charged Particle Precipitation into the Auroral Zone
J. Geophys. Res., 76, 3612-3643, 1971

T. P. ARMSTRONG and S. M. KRIMIGIS
Statistical Study of Solar Protons, Alpha Particles, and $Z \geq 3$ Nuclei in 1967-1968
J. Geophys. Res., 76, 4230-4244, 1971

J. A. VAN ALLEN, J. F. FENNELL, and N. F. NESS
Asymmetric Access of Energetic Solar Protons to the Earth's North and South Polar Caps
J. Geophys. Res., 76, 4262-4275, 1971

MELVIN N. OLIVEN
Energetic Electron Clouds in the Earth's Magnetotail and Environs
U. of Iowa 70-38 [May 1970]

J. CESSNA
Bit Error Rates and Transient Times for Binary Digital Loop Bit Synchronizer in Additive White Gaussian Noise
U. of Iowa 70-49 [August 1970]
Submitted to IEEE Transactions on Communication Technology

L. A. FRANK
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